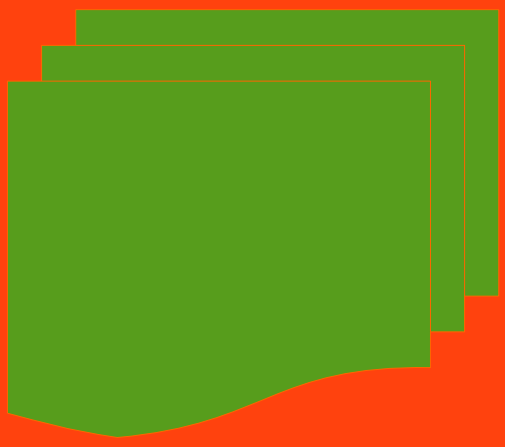
A.P. MARYUKHIN

LANGUAGE OF PHYSICS



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Preface

Language concerns all branches of science. Physics is not an exclusion in this attitude. Positivism showed on its own example the wide range of problems united under the title of theoretical language. My desire to continue this topic goes through many obstacles both epistemological and ontological. I reopened new works to give them the second birth. Theoretical aspects are the main part of this investigation. Once again I throw a look onto physical concepts as an essential attribute of science as a whole.

Astrakhan, 2022

§1. Perception

Every empirical science presupposes something that is called “the real”. In natural science, the totality of everything real is called “nature”. Knowing what is real is by no means easy. The highest reality, the ultimate judge of all differences of opinion in natural sciences is a direct perception. It is understood as the given that is vividly grasped with the senses in the present, i.e. the sensory experience. Mr Driesch speaks of this as belonging to the first stage of perception – “this tree”, “this house” that I see, feel, etc. In addition to what is perceived in the present, there is much that is imagined in memory as real – the sun that I saw yesterday. This real is not something that is directly perceived, but only something that is imagined in memory, which is added to the perceived real as an earlier real. Mr Driesch also counts what is perceived in memory as part of the “first level of reality”.

The reality of the first stage thus consists of a temporal chain of realities which, like the individual images of a cinematographic film, are ordered by thinking. Thinking also regards as real which is not perceived – the table behind me is real although I do not see it now; the dress in the closed cupboard is real, etc. Mr Driesch calls this extension the “second level of reality”.

The question whether the real lies in the content of perception or in thinking or in both or anywhere else is not to be understood as a matter of opinion that is arbitrary. If you ask a simple man with common sense what he/she thinks is real, he will hardly get the content of his/her own perceptions. He/She will point much more to the bodies around him/her and to many other things, and he/she will declare that all of this is real. This point of view is known as naive realism; it does not represent a contradiction to phenomenology, but it does a strong limitation in the fact that only a small part of the perceptual content is taken into account.

The physical quantities can be determined approximately, so that they belong to the field of mathematics where functions between physical quantities are called “laws of nature”. All natural laws are like that of Boyle-Mariot's law, the equations of motion of mechanics, the electrodynamic basic equations, etc. to be regarded as approximately guaranteed, approximately definable. This is, on the one hand, because of the inevitable errors of observation, (a test of any natural law can only be carried out with limited accuracy), and on the other hand because the definition of the physical concepts, to which the laws refer, relate to perceptions.

The laws of nature are only laws between measures m_1 and m_2. The laws of physics do not tell us what nature is like, but they tell us what nature is made of. Nature can be known approximately; this approximation is the mark of the relationship between thought and real nature.

§2. Conditional and Causal Description of Nature

The description of a natural process is complete when we can calculate it in advance in all its quantitative details from given conditions; then we master the

natural process. The ideal of such a description is thus a mathematical one, and it is understandable, when naturalists and mathematicians work together. In spite of this, the mathematician's deductions are very different from those of the natural scientist: the mathematician's object is the infinite field of logical possibilities, the physicist's object is the unambiguous course of nature. To make the difference clear, consider an example of describing the movement of a falling stone. The mathematical description can be done in different ways, for example by the fact that the speed $dx/dt = gt$ is assumed. Thus the complete condition for the movement is given and clearly defined and no longer allows for ambiguity. Through formal methods of integrating the above equation can be used to draw conclusions, which must be correct because they can only be continued logically in an ambiguous manner and are on the correct basis.

The physical description, however, is not satisfied with this. It is not enough to to be satisfied by conditions and conclusions which lead to a correct result. It requires that the movement of the falling stone is causally substantiated. A causal description would be something like this: the stone receives an addition to its instantaneous speed at every moment, it experiences an acceleration g, which is caused by the presence of the gravitation and (in the first approximation) can be assumed to be constant, independent of the height of the fall. The characteristic of this is causal to give the reason, which in each moment of time determines the state of motion compared to the state of motion in the previous instant.

The conditional theories are usually smoother and more convenient to use than the causal ones. This may stem from the fact that the conditional theories are adapted to the logical understanding. The causal theories are devoid of any consideration built on the economy of thought and simply let a temporal-spatial sequence of natural events run in front of our eyes; so the causal nexus is an actually characteristic of natural science; the conditional theory, on the other hand, is a characteristic of mathematical technology in the sense of a logical art.

It is often asserted that scientific progress consists in perfecting our insight into the causal connection of natural events, i.e. in teaching us more and more precisely the spatio-temporal sequence of natural phenomena. That is true as far as it is concerned physical penetration and description, but it is not applicable with regard to the mathematical penetration aimed at the most economical, short and yet complete description of every detail worth knowing. The mathematical treatment of a natural phenomenon turns it into a problem that has to satisfy certain formal conditions, regardless of any causal connection.

The causal description of nature has often been contested, and since Hume's analysis of causality, questions about the cause of a phenomenon have been viewed with suspicion. But it is indisputable that the historical development of modern physics and natural science clearly shows that the causality as opposed to the general conditional connection of natural processes cannot be dispensed with the latter.

The physical terms arise because they are based on observations of natural phenomena and are linked to experience, by thinking of natural phenomena, just as the concepts of daily life come about through abstraction from the perceptions. So the physical term “mass” may have arisen from primitive experience in dealing with

wood, stones, etc. Primitive physical terms are also speed, pressure, light intensity and others. In physical concepts anthropomorphic impacts can occur, which are evidently caused by the human nature. On the other hand, the opinion is held that this impact does not belong to the actual scientific core of a physical concept, but it is rather an arbitrary chosen phenomenon.

§3. Definability of Physical Concepts

The question of definability is posed in general for philosophy of physics, in which its concepts should find a logically satisfactory answer. Such an investigation seems to be urgent. On the one hand, it is not quite clear what physicists actually mean when they speak of the definition of this or that physical term, in short of a "physical definition". Is it an operational definition, a formal definition, or no definition at all in the logical sense? Everything that physicists call "a definition" does not generally stand up to the logical demands placed on such a concept. Therefore, the meaning of the assertion that "physical concepts are definable" must first be explained in more details. On the other hand, philosophers of science often treat the question of the definability of physical concepts as an absolute one. The logical empiricists, for example, categorically assert that theoretical concepts are not explicitly but only implicitly definable. Apart from a systematic ambiguity of the term "implicit", this specificity corresponds in reality to an indefiniteness, namely the indefiniteness of the application of logic to the concepts of physics. This is basically due to a large number of opportunities in terms of the logical means of adequately reconstructing physical theories. Thus, contrary to a widespread view, it is by no means certain that physical theories can be logically reconstructed as theories of the first order.

If one does not want to end up with definability, then it is advisable to look for the causes, which have driven logical empiricism to its undefinability claim, and to reassure oneself of the actual way in which concepts are formed in physics before attempting to apply their definitions. By far the most important doctrine is the distinction between observable and theoretical quantities. This distinction was and is meant as an expression of a Humean or empiricist epistemology, in which the observable quantities are those entities (such as sensory data, physical things, properties, etc.) that are immediately certain for our cognition – in the normative sense that a doubt about them is systematically impossible – while conversely this does not apply to the theoretical quantities. Only two aspects of this distinction, the logical and the epistemic, should be pointed out in their connection.

(i) The distinction is made logically in such a way that the meaning of all sentences (including the theoretical) results solely from the meaning of the observation sentences, their possible meaning {W, F} again is solely a function of the epistemic certainty of our immediate experience. More precisely, it is a double distinction, namely the epistemic distinction of magnitudes and the linguistic distinction of terms. These must be coextensional to one another, i.e. atomic

sentences may only consist of terms whose reference is directly observable quantities, while the remaining sentences can also contain terms that refer to theoretical quantities.

(ii) In contrast, it initially seems immaterial whether the intended epistemic distinction can be made on the basis of a natural language or only on an artificial language specifically introduced for this purpose. This means the following: it seems irrelevant whether the distinction can be mapped directly to the existing physical concepts (or the descriptive vocabulary of an existing physical theory), or whether a language *L* must first be introduced artificially in a "coextensional" way, in which the physical concepts and theories can then be reconstructed. Accordingly, Mr Carnap and Mr Hempel chose artificial languages so that between the descriptive constants $f_1..$, f_n of theoretical and observable quantities, there is a unique mapping such that *L* is divided into three disjoint subclasses: the logical vocabulary V_E, the theoretical vocabulary V_T and the observational vocabulary V_O.

That this alternative ultimately proves to be untenable is the content of the first U-postulate: "It is impossible to represent the epistemic distinction "theoretically-observable" coextensionally to the existing physical vocabulary". The reason for the alleged impossibility is easy to see if one considers what goes "by definition" to the epistemic distinction of magnitudes on the one hand and to the formation of physical concepts on the other. According to the epistemological distinction, every expansion of our knowledge is associated with the introduction of new, theoretical quantities – regardless of whether this is in an extensive direction towards the macrocosm of the universe or the microcosm of the elementary particles or in an intensive direction relatively increasing measurement accuracies or absolute higher resolution. As a requirement, this introduction must be linked to a corresponding extension of the physical vocabulary.

We must instead of "length" or "temperature" have an infinite series of length and temperature terms, which would have to be distinguished into observable and theoretical terms depending on the area of application and measurement accuracy. Every physicist knows that this is not the case because the relevant physical theories are not formulated in such a way that they contain infinite series of length, time, mass concepts etc. or the corresponding sets of functional constants, as "operationalism" explicitly and the "received view" implicitly demand. What we have instead are unlimited sets of possible applications of one and the same theory formulated in a few general terms; technically speaking, the physical terms are (usually) functions from an infinite domain into the real numbers, whose values can be determined more or less reliably depending on the application. At the same time, this analysis of the physical concept formation enables a realization of the corollary that deviates not insignificantly from that of the "received view".

(i) Without having to resort to an "artificial" language extension, the epistemic distinction in physics can be justified by reconstructing it as a distinction between the areas of application of a theory in secured and unsecured applications and not as a distinction of concepts. For, physically speaking, the distinction "theoretically-observable" concerns only an intra-conceptual difference in terms of the epistemic

certainty of the applications of a theory and all its concepts, which can therefore by no means be represented as an inter-conceptual difference between the various physical quantities of a theory.

As far as such an inter-conceptual difference is concerned, which is coextensional to the actually existing concepts of a physical theory, it is clear that this cannot concern an epistemic distinction of cases of application, but must be a distinction of physical magnitudes that is related to the objective meaning of the terms. Some terms specific to the theory acquire their objective meaning by establishing a connection between them and the meanings of other terms of the theory, or, as physicists say, by the laws of a theory. What is involved here is therefore a semantic difference of the objective meanings, which corresponds to the syntactic formulation of the concepts in the logical structure of the theory, and *vice versa*. Ideally, this must be completed before the theory can even be applied and thus epistemicly verified; i.e. the actual error of the "received view" lies in the precedence of the epistemic over the semantic distinction. But what are the criteria for such a semantic distinction?

Sneed's "measuring-methodical" criterion leads to a distinction between theoretical and non-theoretical quantities of a physical theory *T*, which intuitively adheres to the terms given by *T*. Without the criterion leading to an adequate distinction of terms for this reason alone, it is interesting to note that the intended distinction does not meet the requirements of the "received view"; it cannot be an epistemic, but ultimately only a semantic distinction in our sense. From the position of the "received view" (and only from this) the following objections can be made against the one intended by Mr Sneed:

(a) The T-theores of a concept should obviously depend on the method of measuring the quantity, i.e. on the area of application of the theory *T*. So the concept of "length" applied to the distances of the planets in Newtonian mechanics would be a "theoretical" concept, while the concept of "gravity mass" in everyday life is a non-theoretical concept, because a simple beam balance – whose lever laws do not require Newtonian mechanics – is sufficient to determine the weight. Such a dependence of the theory on the area of its application is inevitable.

(b) This proves, among other things, the fact that the "measurement error" when applying a theory can be expressed by any of the quantities covered by the theory, e.g. the accuracy of the planetary masses by the accuracy of the trajectories, and *vice versa*.

(ii) What is essential about the significance requirement is that the empirical significance of theoretical terms – in the sense of the distinction once made – is exclusively an epistemic reduction, i.e. a reduction by which the possible meaning of theoretical statements is reduced to the meaning {W, F} to be traced back from observation statements. In this way, the meaning of theoretical statements – just like the observational statements – becomes a function of the meaning, i.e. the epistemic certainty of observational statements. Behind this is obviously the epistemological idea that our world is epistemically graduated into areas, so that we can progressively expand the meaning and thus the certainty of our statements logically from

application to application.

(iii) In contrast, the logical form of the reduction appears to be secondary. This was initially conceived as “explicit definitions” of the theoretical terms by means of the observation language, but then had to be used because of the so-called disposition predicates for “conditional definitions” in favor of an “axiomatic” construction of theories. The theoretical quantities are introduced as empirical – not mathematical – uninterpreted terms, which only receive a “partial” empirical interpretation through the meaning postulates.

This is only significant to the extent that it can be empirically confirmed in individual applications. The reasons for the weakening of the epistemic reduction requirement are easy to discern: if one considers that most physical concepts are functions (into the real numbers), there is generally no prospect of defining the functions by the (fundamentally finite) empirical determination of their value courses in all applications (in the logic of the first level).

Inasmuch as there are two distinctions in physics – one of concepts and one of applications – there is also a double reduction problem, which in each case must become unique: firstly, the semantic reduction of the concepts and, secondly, the epistemic reduction of the applications of a theory. Methodologically, the semantic reduction forms the prerequisite for the epistemic reduction. In a first approximation, semantic and epistemic reduction means the following:

(i) Suppose we had a presuppositional distinction of a coextensional kind between the “contents” of a physical theory on the one hand and its existing concepts on the other. Precisely in this case of a deductive dependency, there is also a need for a semantic reduction in order to check the terms in their semantic consistency and dependency on meaning. This necessity is particularly evident where no epistemic difference in the applications of a theory is superimposed on the semantic difference, e.g. in theoretical physics, where there is hardly any talk of empirical applications. In physics, the semantic reduction does not consist in the theoretical “observable” sizes, but in the projection of certain legal statements and their terms onto the level of contingent statements and their terms. The semantic reduction of a secondary term consists in the representation of its “objective” meaning through the legal context of the otherwise only contingently connected meanings of primary terms. So for example, the concept of “carrying mass” precedes the concept of “movement”, and this in turn precedes the concepts of “space” and “time” in order to be able to “define” at all, in which the “objective” meaning of this concept consists: namely in the (up to coordinate transformation) unambiguous characterization of certain ratios of otherwise contingent velocities of the impacting objects before and after the impact. The semantic reduction is expressed in the fact that certain statements about secondary variables at the same time legally imply certain sets of statements about primary variables in the sense of presuppose and follow, i.e. are logically in an equivalence relation to each other.

(ii) An epistemic difference between the applications of a theory already exists when the statements of the theory in one application are relatively uncertain compared to those in other applications. The absolute epistemic difference between

the applications of a theory is determined by the fact that the values that go into the theory are already known in one application of the theory, while in another application they are at least partially unknown. This absolute epistemic difference is therefore also a difference that cannot consistently be coextensional to the concepts of a physical theory, but must be coextensional to those structures of a theory that are in turn coextensional to the applications. However, these are precisely the mathematical structures, i.e. the *n*-tuples of function values of all *n*-functions or concepts of a theory that are models of this theory. In this absolute case, the epistemic reduction consists in determining the unknown function values of an application from the already known function values of one or more other applications. The fact that the epistemic reduction is necessary in certain (not all) cases follows from the fact that there are applications in which not all function values of a theory are determined *ab ovo*, i.e. by direct measurement. Rather, there are applications in which the values of secondary variables cannot be calculated solely from the values of the primary variables in the same application, but the values of primary or secondary variables from other applications must be assumed to be known.

Taking into account approximate aspects of accuracy, the epistemic reduction is presented in such a way that it is carried out invariantly with respect to the semantic order of the concepts, even entire theories. On the other hand, it has already been mentioned that even an abstract epistemic reduction or reduction chain is not free from any semantic reduction. This must come into play at least at the point where there is the first application of a theory. Ultimately, every epistemic reduction rests upon the possibility of a corresponding semantic reduction, insofar as the validity of a theory in any application can only be proved by the fact that the primary quantities satisfy the relationship that the secondary terms legally require them.

§4. System

Physical theories relate to systems. A theory is applied to an empirical system and checked on the basis of observations; each measurement is made in a system. Only verified relationship between a theory and the real system gives the theory empirical significance. Therefore, we must first address the question of what a system is. A typical definition found in the literature is the following: „A system is a set of objects together with relationships between the objects and between their attributes".

Accordingly, the following features characterize a system:

– a system is a structurally self-contained unit that is set apart from its surroundings (environment);

– a system consists of parts (objects and their attributes) that combine to form a functionally complete whole;

– a system consists of elements that are connected to each other by relations;

– a system can assume different states that can change over time;

– a system is an idealized object that is prepared from empirical reality through mental abstraction. Systems are constructs that are not "found" in reality, but are

modeled by the subject. A system is an object that is distinguished from its environment by an observer.

We want to take a closer look at these contrasting features. For example, why is the distinction between a system and environment constitutive for a system? Mr Luhmann gives us the answer to this question: “A system can only preserve its identity and its conceptual unity if it is separated from its environment because identity is only possible through difference”.

The boundary between a system and its environment is not fixed by nature at all, but is based on a definitional determination. The limits of a system are set by humans as a system observer. Everything that does not belong to the system is excluded as environment. The environment is only a “negative correlation of a system”.

The well-known distinction between open and closed systems is also based on the difference between system and environment. From the outset, there are no operationalizable criteria for defining this boundary between the system and the outside world. This is due to the extensionality of the definition. It should be noted at this point that this boundary is drawn according to the interest of one's system, i.e. it is based on hypotheses. At this point at the latest, it makes sense to refrain from asking about the reality of the systems.

A closed system is characterized in that there is no interaction with the outside world. However, such a seclusion cannot be realized in practice. An object is never completely isolated from its environment, no system is complete in every respect. For example, in classical mechanics, every closed system is in gravitational interaction with its environment, and this type of interaction is quite relevant to mechanics.

Let us consider a laboratory as a closed system. A body falls to the ground only because it is attracted to the earth. So a force is exerted on the body by the environment and therefore the laboratory cannot represent a closed system in the sense defined above. Strictly speaking, closure can only apply to the universe as a whole. But it is doubtful whether the universe can be called “a system” at all. Since by definition it has no environment, no “outside”, the system-environment difference reveals and thus the universe is not a system in the sense of our definition.

But there is another reason why a system can never be isolated from its environment free of interaction. A completely closed system could not be observed. Observation and closure are reciprocally related: insofar as a system is closed, its inner working is not observable and insofar as it is observable, it cannot be closed.

System theory is a heterogeneous discipline that is broken down into different schools, each with a different system concept. Today one can distinguish between a sociological system concept (Parsons, Luhmann), a formal system concept (Mesarovic), a technical system concept (Ropohl), and a cybernetic system concept (Ashby). General system theory attempts to establish a common conceptual basis and a generally accepted basic vocabulary applicable to all systems.

A system description in the simplest case, if one disregards more complex relationships, is given by the following basic concepts (primitive concepts):

1. The system consists of a set of objects.
2. These objects can be assigned a variety of attributes (e.g., size, shape, color,

texture, etc.). Then one can describe these atomic objects by specifying properties and qualities. If necessary, these object properties can even be quantified or measured, i.e. each element can be assigned a variable, state variable or mathematical function (e.g. impulse, force, temperature, etc.) that can assume specific values (e.g. real numbers).

A system consists of

1. a set of attributes;

2. a set of functions that describe relationships between the attributes of a system;

3. a set of subsystems, and

4. a set of relations between the subsystems. Subsystems are components of a system, which in turn have attributes and functions. Analogously, there can also be sub-subsystems, etc., just as one can combine different systems at a higher level into super systems.

A system thus represents an entity that (a) exhibits relationships between certain attributes, which (b) consists of interconnected parts or subsystems and which (c) is delimited from its environment at a certain level or excluded from a super system. Three aspects are important:

a) the structural aspect, which regards a "system as a whole of interconnected elements";

b) the functional aspect, which characterizes a system as a "black box" with inputs and outputs, and

c) the hierarchical aspect, which makes it clear that systems are hierarchically divided into subsystems and super systems. Every system description is in a dialectic tension, which is dominated by the poles of part and whole, superiority and subordination. This relationship gives the cognition process a paradoxical circular form. In this context, Mr Kornwachs speaks of paradoxes of description. They necessarily appear in any kind of system description. Two of these system paradoxes are the paradox of wholeness and the paradox of hierarchy.

Paradox of wholeness

If the whole can only be described by its parts or by division (which is the condition for the definition of structure), then the parts can only be fully described if one considers that they belong to a whole.

Paradox of hierarchy

The complete description of a system (structurally seen) would only be possible if one considered that due to the existence of a class-foreign element, the system to be described represents an element of the higher-level system. The description of the system as an element of the higher-level system is only then possible, if the system to be described is already described.

In fact, these paradoxes of description make it clear to us that understanding a system always has a circular (or better "spiral") structure. We enter the circle somewhere by bringing in our prior understanding, correcting our prior knowledge, thereby producing new knowledge, and the cycle begins again.

The totality of all properties of a system at one point in time is called "the state".

The mapping that takes a system from one state to the next is called “a transition” or “a transition function”.

The structuralist philosophy of science pretends that systems are indivisible, unstructured units. In the structural theory, systems represent elements of model sets (M, Mp, Mpp). As such, they have no internal structure. (Members of sets never have any structure). But in physics what matters is to describe the inner structure of systems, their properties, qualities and quantities. The physicist is particularly interested in the data. There is no adequate expression for this data material in the structuralist theoretical model. Empirical data does not belong to the set of models *M*, nor to the potential models *Mp*, nor to the partial potential models *Mpp*. It seems as if these aspects were not relevant at all to a structuralist. A structuralist seems more interested in the structure of theories than in the structure of the world. But theories are there to help us understand the world better. If the final state is L_1 through the initial state L_0 and the boundary conditions are fully determined, then it is a deterministic system. Particles that move, according to Newton's laws, form a deterministic system, since Newton's equation of motion determines all future states in advance.

§5. Model

Previously we have seen that systems are defined, structured and used by humans. They are therefore products of man and do not exist in nature as entities in themselves. Humans select certain characteristics of reality and summarize them as a functional or structural unit under the term “system”. This shows that every system formation is an abstracting, idealizing process. Systems are simplified, idealized, classified into conceptual categories and thus supplied with a theoretical description. A simplified image of reality is created. The concept of the “model” requires a more detailed explanation. Mr Stachowiak characterizes models by three features:

1. Models are always models of something, namely illustrations, representations of natural or artificial originals, which can themselves be models;

2. Models generally do not capture all attributes of the original they represent, but only those that appear relevant to the respective model creators and/or model users;

3. A model is a set of statements ascribing properties to some object or system;

4. The statements that constitute the model describe some item assumed to be distinct from that of which it is a model;

5. A model is designed to provide an interpretation for an uninterpreted formalism or calculation;

6. A model is always proposed with reference to some theory;

7. Models are not *per se* uniquely assigned to their originals.

The main features can be summarized in five points:

1. Models are copies or representations of a real object or system. The model itself can be material or imaginary, it can be an imitation of the original or it can be a

theoretical model. Model is the most comprehensive expression for the symbolic representation of real facts and systems. From this point of view, everything is actually a model.

2. The model has at least one property in common with the original. The model must be similar to the prototype to a certain degree, it should approximate the real situation. The similarity of the model with the original can be low (simplifying models), in the limit it can even be up to a structural isomorphism, rich isomorphs or adequate models.

3. Every modeling includes an abstraction. With this abstraction, certain properties of the original are lost, i.e. not all properties of the object can be transferred to the model. There must always be a property in which the original and the model differ, since otherwise both were identical because they were indistinguishable.

4. Models are made by humans or declared as models by humans. Humans use models to achieve a specific goal. Model is the supposedly objective cognitive structure as well as the thought construction that emphasizes its subjectivity and perspective. Model is Newton's particle mechanics as well such as Ranke's world history or Holderlin's hyperion. All of this is a “model”, with respect to its “objectivity” it differs only gradually from the exact scientific theory.

Any model possesses following features:

– Functionality: Models are made to perform specific functions. Often they are preferred over their original because they are simpler or easier to use.

– Simulation: Operations are to be carried out and tested on the model that cannot be carried out on the original object itself, or only with great difficulty. The model replaces the original on a trial basis.

– Explanation: The model should explain certain phenomena or the behavior of objects.

– Prediction: Sometimes models also need to be able to make predictions about the future behavior of objects.

5. Every model contains implicit theories which regulate the relationship of the image (= model) to its originality or which make the construction of the model possible in the first place, e.g. in its formulation as a mathematical model. In this respect, each model is theoretical.

The explanations show that there is a close connection between theories, models and systems. In any description of systems and models, theories are involved. Systems, models and theories are three stages in the cognitive process, with systems determining the lowest level, the object level. An object only becomes an object of cognition for us when it is classified as part of a comprehensive system or is already a system itself. Models are an abstract and idealized depiction of systems. There is a qualitative difference between models and systems: models are usually more accessible and manageable than the systems they describe.

The model itself determines the rules for dealing with it. The user or designer can make the model as simple as possible through his active design options. Systems do not offer such unlimited opportunities for intervention.

So far it has always been said that models are images, reconstructions or representations of objects or systems. Although such a definition is found almost everywhere in the scientific literature, this definition must be critically questioned, since it tacitly assumes an image theory of knowledge, according to which adequate knowledge consists in an ideal correspondence between model and reality. Mr Stachowiak relativizes this objectivist claim in his neopragmatic model theory and recognizes that knowledge depends on the subject and is guided by interests: “Models are representations, but they usually only represent their originals for certain subjects (the model users). Every perceived object is itself a model because in every perception of an object, the schematization of our mind already enters, which constitutes the object as a phenomenon. If we consider this, we can certainly speak of the model relation as a mapping, but now no longer between model and reality, but between the model and the sensual appearance of the object”.

Each model is constructed under the guidance of a theory, but models and theories must not simply be equated. The difference between theories and models is this: Models are object-related theories, they describe a precisely definable and delimited subject area, namely special systems. Theories, on the other hand, do not necessarily have to be assigned to a specific subject area; their subject area is open. Theories can only be tested using models. Model-free theories cannot be tested empirically.

By themselves, the extremely general theories, such as information theory, and even theories of intermediate breadth, such as quantum mechanics, are untestable. What can be tested is only a specific theory, i.e. a theoretical model, whether or not is the outcome of attaching a model object to a generic theory.

Theories are logical-mathematical structures that, by means of an interpretation, describe certain aspects of reality. Here is an example: The quantum theory says absolutely nothing about atoms or elementary particles. These objects have to be introduced by phenomenological models (e.g. Bohr's atomic model) and can then be treated quantum mechanically. But they are not already given by the theory. Many theories in solid state physics are basically not theories but models. Although they make use of quantum theory, they apply it to concrete physical systems, such as crystals or semiconductors. This object-relatedness is typical for models.

Models are necessary for the interpretation of a theory, they form a bridge between theory and reality. In terms of the history of science, models are usually developed before theories. This becomes clear using the example of quantum mechanics: before quantum mechanics was developed as a theory by Mr Heisenberg, Mr Schrödinger, Mr Dirac and Mr von Neumann, physical research at the beginning of this century dealt with certain phenomena and systems, e.g. black body radiation (Planck), the photoelectric effect (Einstein), the diffraction of matter waves at crystals (Davisson and Germer) or the characteristic spectral lines of atoms (Balmer and Ritz). All of these investigations were limited to specific physical systems: black bodies, atoms, crystals, etc. Models were developed to describe them and individual laws were also discovered: e.g. the wave-particle duality according to de Broglie's or Bohr's and Sommerfeld's atomic models. Only after these models could a new theory

be set up to explain all these phenomena. could and was applicable to each of these models.

Another difference between models and theories is noticeable in this historical excursion: theories must always be logically consistent (free of contradictions), while this is not always the case with models. For example, in de Broglie's model, the property of an electron being both a wave and a particle is logically contradictory. But on the theoretical level (quantum mechanics) this contradiction is resolved. Every quantum mechanical object is described by a wave function that contains both momentum *t* and a wave vector *v* can be assigned. Particle and wave properties turn out to be two complementary aspects of one and the same object. The system-theoretical model concept presented here must not be confused with the mathematical model concept.

Mathematical logic uses the term “model” in a different sense. There the term denotes a real or imagined ideal system that satisfies the axioms of the theory. If *A* is a set of formulas, then *M* is a model of *A* if *M* satisfies every formula of *A*. A mathematical model represents an interpretation of a system of axioms. In semantics, and particularly in model theory (the semantics of pure mathematics), the term “model” signifies an interpretation of an abstract theory, under which (interpretation) all the statements of the theory are satisfied (or true). An axiom system or theory is said to be monomorphic or categorical if any two models of the theory are isomorphic. So up to isomorphism there is only one model of the theory.

In mathematics and in physics, model means something different. The mathematical model denotes an object area in which the formal relationships postulated by the theory apply. In contrast, the system-theoretical concept of “model” means a constructed theoretical image of reality. The structuralist philosophy of science uses the concept of “model” in its mathematical meaning. We understand the term “model” here in the sense of modern logic and model theory. Models are, therefore, those “things” depicted by a theory.

Anything to which the mathematical structure *S* is applicable is called a “model of *S*”. Models are systems that satisfy all the requirements of a set-theoretic predicate. Any physical system which satisfies this predicate shall be called a “model of the physical theory in question”.

Here it would be interesting to ask whether the axiom systems of physics are of a categorical or non-categorical nature, i.e. whether there is only one single model for a physical theory or whether there are many different, non-isomorphic models. In the first case, the real world would be the only application of the theory, otherwise the universe would fragment into a multitude of separate models. Mr Sneed and Mr Stegmüller clearly prefer the second interpretation: a theory does not have a single, universal area of application, but rather many different intended applications.

The logical-mathematical model is completely unsuitable for the reconstruction of empirical theories. In mathematics, it can always be clearly decided whether a given mathematical object is a model of the theory or not: for example, a class of geometric rotations forms an algebraic group or not, there is no third alternative. There is always an ideal correspondence between object and theory because

mathematical objects are themselves ideal. In physics, on the other hand, the correlates of model relationship are totally different; here the construct (theory or model) has to be compared with reality. The relation between theory and experience is not a two-valued alternative according to which a real state of affairs is either a model of the theory or not. Rather, there are different degrees of fit between model and reality. The empirical data can agree well or poorly with the predictions of the theory, depending on how well the theory has held up to experience. In between there is a whole continuum of degrees of fit. The quality of a model depends on its degree of correspondence with reality, but also on its functionality and usefulness. Therefore, the logical-mathematical model concept cannot be applied to empirical theories at all.

By characterizing theories by set-theoretic predicates applied to real systems, structuralist philosophy of science asserts that the predicate either applies to a system *x* or not. However, the validity of a theory cannot be established on the basis of a simple yes or no decision. Deciding whether a theory is valid or not is a pragmatic decision based on values such as simplicity and accuracy. These values can change historically because they are part of a paradigm.

But there is another reason why the structuralist approach cannot be accepted. Mr Sneed distinguishes models *M*, potential models *Mp* and partial potential models *Mpp*. *M* contains the axioms, *Mp* consists of the terms of the theory and *Mpp* is restricted to the non-theoretical vocabulary of the theory. Correspondingly, the associated set-theoretic predicates can be defined: "*x* is an *M*", "*x* is an *Mp*" and "*x* is an *Mpp*". How can these predicates be assigned to concrete physical systems? In the first case, when we consider models, this is somewhat understandable: a system *x* is a model if and only if it satisfies the laws of the theory. But how should the criterion for the potential models or partial potential models look like? It is said that a system is a potential model if and only if physical functions can be assigned to the objects of this system (e.g. particles). This is easy to realize. In principle, you can attribute energy, momentum or force to every conceivable object, as long as there are no conditions attached to these quantities. It is always simply to choose the zero function; then every system becomes a potential model. If you disregard every law, then the functions of force, mass or energy lose their physical meaning. One cannot declare an object to be a potential mechanical system by saying that it has positive mass and its location is a twice differentiable function of time. Such ways of speaking say nothing about the physics of the systems under consideration; they rather have the character of arbitrary definitions. In this way one could grant each mental object of the desired functions and thus derive a potential model of classic mechanics.

Let us make it clear: an object only becomes a possible physical system if one can specify laws that give it a formal structure, because physical quantities are implicitly defined by their axioms. It is the same as with the mathematical terms. In mathematics, it is meaningless to formulate axioms in such a way that only certain functions are required to exist without adding which laws these functions must obey. The actual content of axioms should establish relationships between quantities that are initially undefined. For example, to know what a point, line, or circle means, one must know the geometric axioms in the context of which the terms are used.

It is the same in physics. The dispute as to whether Newton's second law is an empirically unverifiable hypothesis, a conventional determination or a hidden definition of force is irrelevant in this respect. Force and mass in Newtonian mechanics are defined by the totality of all axioms and therefore cannot be measured independently of them. The set *Mp*, which contains only a series of physical variables, is empirically meaningless. Physical reality cannot be described by mathematical functions alone. Every system description requires laws that create a relationship between the individual variables. The sets *Mp* and *Mpp* taken by themselves therefore make no sense. This is another reason to reject the structuralist approach.

§6. Space

There is still considerable disagreement about space. Aristotle thought that space was an abstraction from sense things. Berkeley believed that it was extension and shape of sensory qualities. Hume said, “We don't have one expression of space or extension, insofar as it is an object of feelings”; Hume claimed that the representations of the primary qualities (e.g. space) are abstract entities, all incomprehensible and absurd. According to Kant, space is a pure *a priori* concept of understanding, not an object of perception, but the form of all appearances of external senses, a way in which the manifold appearances can be ordered. Mr Gauss thinks that one must admit that space has a reality outside of our minds for which we cannot completely prescribe its laws *a priori*. Mr Stump takes the view that space is perceived originally and directly like qualities, since they form an inseparable content.

The opinions of the various thinkers seem less to contradict one another than to pass one another by, in that the word space has one meaning at one time and that one at another; so Mr Gauss and Mr Helmholtz think apparently of physical space, Kant thinks of the general concept of “space”, the mathematician Poincare of the logically possible mathematical spaces.

§7. Time

Space and time are usually treated together, and Kant already discussed them together. In fact, the properties of both are the same in several respects: each is conceived as a continuum, both are unlimited, both are measurable in their parts, both are separated as primary from secondary qualities. But we also have differences: space is multidimensional, time has only one dimension.

According to Aristotle, time (like space) is supposed to be an abstraction from things, namely from sense things. Correspondingly, Newton stated that time was usually understood as relating to the senses, but Newton himself established the fundamental propositions: “The absolute, true and mathematical time flows in itself

and, by virtue of its nature, is uniformed and unrelated to any external object. It is also called “duration”. Kant teaches that time is not an empty, infinite, absolute absurdity that exists in itself, but nothing more than a “setting of one's ideas”. Time is “a way in which the manifold of phenomena can be ordered in certain relationships”; “the objective sequence of events is a construction of knowledge based on the establishment of a causal connection between events”. Mr Mach thinks that absolute time, regardless of any change, is an idle metaphysical concept. On the other hand, “we feel the time or the temporal position directly”; “without a sense of time there would be no chronometry”. Mr Poincare simply says, “There is no such thing as an absolute time”. Mr Lindemann, on the other hand, thinks that “based on experience, one can speak of an absolute time”. According to Mr Natorp, “time is a condition of possible experience, as if it was on the boundary between mathematics and empiricism”. As for Mach's expression, time and space are “sensations”. But time (like space) is given as a property of some perceptual content or sensation content.

The measurement of time is of the most fundamental importance for the exact natural sciences; the whole structure of physics rests upon it. In the case of space, measuring a distance can be traced back to something real, a physical yardstick, and we can easily define the removal of the yardstick from the length to be measured and the number of these operations as a length measurement. But what should mean the same length of two periods of time?

If, as usual, we use a movement process, be it a clock or the rotation of the earth, we get into a circle: either we assume that these movements are uniform or we take this process as the basis for measuring time. But why do we then set our clocks “correctly” and ask about the “constancy” of the Earth's rotation? In view of these circles, one would almost recommend giving up the measurement of times and going back to the more primitive method of identification tags, which we have already mentioned in relation to space and temperature. In fact, when describing historical events, we often use time stamps instead of the time numbers, and speak of the time of Pericles, the time of Alexander the Great, the Renaissance period, etc., without always thinking about the corresponding years before and after the birth of Christ. But this method of forming a time scale is not sufficient, despite its advantages of the numerical scale.

§8. Force

The concept of “force” in physics is originally and unmistakably linked to sensory perception. As the name “strength” suggests, it is muscle exertion, e.g. the arm, when lifting a weight, which gives the physical concept of “force” the natural and immediately illuminating base. The physical concept of “force” is thus built on a physiological-psychological basis; it is purely anthropomorphic. Leibniz expressed himself very tellingly that force is “something analogous to the soul”.

The differences between the various physical forces do not relate to the concept of “force” itself, but only to the mode of production. When we stretch a rubber band

with our hands, we generate an “elastic force”, namely due to the property of the rubber, called “elasticity”. If we hold a piece of iron in one hand and magnets in the other, we can observe the “magnetic force”. Thus, the physiological-psychological basis, the perception of the force effects of natural bodies, is always the same, but there is a difference in the technical apparatus for generating the forces.

Physics tries to free itself from the subjective content as much as possible. This happens firstly by idealizing the process and then by making the idealized process measurable. For example, the scale of the different sized forces is suggested by different sized weights, e.g. by different sized stones or pieces of metal, which exert different sized pressures on the hand.

But that does not end the idealization. Experience has shown that the scale of weights that creates a scale of pressure and muscle sensations is related to a class of phenomena which, like no other, appear suitable for producing an accurate and reliable objectification and measurement of the facts: with movements. Every pressing piece of weight, every stretched rubber cord or spring, every magnetically attracted piece of iron starts moving as soon as we give in to the pressure. On the other hand, every body in motion pushes as soon as we inhibit movement.

So it is not far-fetched to try to measure force through movement. But the matter is not so simple here that the greater pressure would always correspond to a greater speed. It is true that the more I squeeze one and the same steel spring, the faster it will move when it is released. But different steel springs, which exert almost the same pressure, are able to perform movements at very different speeds, and pieces of weight of different sizes fall to the earth at approximately the same speed. The movement alone is not able to characterize and measure the force, the carrier of the movement also plays a role. If one wants to relate the magnitude of a force to the strength of a movement, then movement and what is moved must be taken into account at the same time. From this it can be seen that the concept of “force”, as soon as it is related to a process of movement for the purpose of measuring force, is most closely connected with the theory of movement. Historically, the class of phenomena most easily accessible to observation, the mechanical, has proven to be particularly conducive to this development of the measure of force, as in the following paragraph is detailed.

§9. Temperature

The concept of “temperature” shows with particular clarity how a physical concept is created and how it, as a real, empirical concept, has an approximate accuracy and a limited area of application. When it comes to temperature, we are free of all *a priori* accessories, here we are dealing with an undisputed empirical object, here the idealized scale of temperatures is undoubtedly abstracted and constructed on the basis of sensory perception, and so one could do something about time and space to learn from studying the concept of “temperature”.

If the temperature is taken from the direct perception, it should be clear without

further explanation; everyone knows, for example, the unbearable extreme temperatures from everyday life experiences. We therefore have a popular physiological concept of "temperature" and a scale of temperature marks, the qualitative character of which is fixed, i.e. freezing point of mercury, melting point of ice, freezing point of linseed oil, etc. This order of temperature marks is only less expediently than an order of numbers, and it is clear that the well-known measures of length, time, weight, etc. have to be brought to an analogue scale. Mr Mach has explained in detail the difficulties that arose here, and we have to emphasize that this scale is linked to an arbitrarily selected process, the expansion of the body. Just as with space, time and speed, we are faced with the question of whether the temperature scale once defined has finite limits or is infinite like the scale of numbers. While such limits are not fixed in physical space and time and can only be discussed as a non-visual possibility of thinking, they are as good as fixed in the case of temperature: the temperature scale appears to be limited by the state in which the molecules have zero velocity.

Today in the temperature scale most commonly used in physics is not based on the thermal expansion of a randomly chosen body such as mercury, like the older ones of Celsius etc., but is based on the behavior of a class of natural bodies in a particularly simple state, the gases. The so-called "thermodynamic temperature scale" is derived from the behavior of the gases when there is a change in energy. In general, it is noteworthy that the thermodynamic temperature scale is particularly useful and economical because it follows the quantitative laws of heat phenomena.

§10. Dimension

In contrast to the concept of "force", the concept of "mass" is not directly and simply suggested to sense perception. There are two classes of phenomena led to the concept of "mass": inertia and gravity. As far as the inertial mass, which is more original and accessible to primitive technical experience, is concerned, this concept, like the concept of "force", is linked to certain simple observations, e.g. when lifting and moving stones, wood and other natural bodies. If at this level of physical knowledge the concept of "force" reflects the active side of the process, the concept of "mass" presupposes the passive behavior of the body. The body seems to offer a resistance to the force during a movement process; it requires different forces in order to roll or lift the different sized stones or pieces of wood. This is how the concept of the "inertial mass of a natural body" emerges in connection with inertial resistance: the greater the resistance is, the greater the force is required to move, and *vice versa*: the greater the available force is, the greater the mass can be moved or lifted.

In these simple experiences, as one can see, two different terms are interwoven. The inertial mass allows the passivity of the mass to emerge; it is measured by movement in such a way that the measure of the mass is the same as the measure of the force. This relationship is expressed in the equation $K = m \cdot d^2s/dt^2$. Basically, however, the force is to be seen as the primarily given, the mass as the derived. The

above equation contains a fact of experience in that it generally states that for any speed *ds/dt* should be valid. The inertial mass of a body turns from an absolute constant to a constant only for speeds that are not too great. Theoretically, the mass has often been characterized as “the amount of matter contained in a body”. But for us here the mass is a derived term like the energy.

§11. Identity

Plato was the first who separated “is” in the sense of “is identical” from the copula of judgment. Later Aristotle introduced numerical and generic identity and orientated the philosophical problem of it to the question of what makes an individual thing such as it might be. Thus he linked the problem of identity and the problem of substance that lasted until Leibniz. At the same time, the pre-Socratic problem of the conditions under which something can be the same and yet the subject to change predominated in this period.

Leibniz wanted to make the principle of identity mathematically manageable and defined the individual as a non-repeatable combination of instantiation of predicates. The law says that two (things) are identical with one another if one is substituted in speech by another without changing the truth or falsity of this speech. Kant countered this principle with distinction between numerical and conceptual difference. Things are different in number because of their position in the field of vision. The relations in which they stand there cannot be traced back to intellectual differences and therefore cannot be understood from the predicates of things. In this respect, individual things cannot be explained from the concept of “substance”; they are primarily “objects”, that is, givens in the visual space, which must be identified in a unified context with the help of functions, including substance. Identity is therefore for Kant only a conceptual aid for marking distinctions and not a principle that can have a place in ontology. Nevertheless, he wanted to attribute identity to the principle of unity, from which the unitary context of objectivity is to be understood as a property which belongs to it in unavoidable, *a priori* evidence.

The idealistic philosophy that followed Kant was thus encouraged to make experiments, first with the subject as an identity principle and then with the sense of identity that had been ascribed to the subject, even without attachment to self-consciousness. But what is it that is said here to be self-identical? Or to what extent can it be said that identity as such is itself one in which all difference finds its origin? The identity, which can be understood as the relation of an individual to himself, is thereby made self-reliant once again. Here, the philosophical monism encounters the articulation difficulties for which Hegel made the most impressive efforts to overcome.

When Kant claimed a sense of identity exclusively for the consciousness of the thinking subject, he also found a connection to the Anglo-Saxon debate on identity that Hobbes, the greatest critic of Aristorelism, had initiated. Hobbes dismissed the idea of substance, among many others, by arguing that we do not ascribe an object its

identity according to what it is metaphysically, but according to the point of view from which it was given a name. Thus a man can remain the same so long as his thoughts and actions arise from the same causes, even though metabolism leads to the complete replacement of all matter in his body. On the other hand, if by the name “ship” we mean a specifically designed matter, a ship will no longer be the same ship when all the parts that made it up have been exchanged. With this literally nominalist's theory, Hobbes took the first step towards the modern theory that all general terms have meaning only in conjunction with specific “criteria of identity”.

John Locke reinforced Hobbes' reduction of the role of the concept of “substance” in our worldview by examining the condition under which we address persons as the same, and by moving it even further from the notion of a persistent entity. Locke observed that we consider a person to be the same when he/she can remember his/her previous states, no matter what body shape or what powers are attributed to him/her. What persists in a person's life is just one way in which ideas are related to other ideas.

18th century English philosophy was fascinated by this thesis and discussed it at length and vigorously. David Hume drew extreme conclusions about it. He stated that there is nothing at all in the associative context of our ideas that allows us to consider the talk of an identity of the person to be justified, and he also considered identity to be an unfounded illusion: a single thing can have unity, but not be attributed to identity, since identity must mean a relation of something to something. However, by definition, several things cannot be identical.

Identity is a fiction that hypostatizes the continuity in changing our conceptions of things as a property of things. Hume admitted, however, that his diagnosis falls short of the reasons that seem to make it impossible for us to deny an inner unity to our own imaginative life, and he concludes that the question of these reasons raises a problem which, while he must acknowledge, which he could not solve within the framework of the principles of his philosophy. This highly remarkable self-limitation of his theory, which was also unique for Hume, also made Anglo-Saxon philosophy listen to Kant's attempt to find a solution in a completely different theoretical context. Conscious unity seems to be of quite a different formal nature than thing unity. It could be that whoever can describe the unity of the nexus of consciousness has the means to introduce a peculiar and privileged sense of identity into philosophy and to defend it against David Hume's criticism. Mr James interpreted the unity of consciousness from its time structure and thus gave Husserl's phenomenology an orientation for the analyzes that Husserl and with him Heidegger considered to be the most profound. But in order to be able to bring clearly into view the basic connection which makes consciousness unified in itself, Mr James has distinguished and separated from it other concepts of unity which denote the unity of the person.

§12. Entropy

Entropy is a physical term that only emerged at a high level of development in

science and that has absolutely nothing primitive attached to it. It cannot be addressed as descriptive either. The concept of “entropy” is thus a school case of an abstract physical concept formed by science itself; on its historical origin, see in particular the explanations by Mr Mach. Entropy in its original form can of course be measured using a unit of entropy. A peculiarity of entropy is that, as follows from recent studies, it refers to a collective object and only characterizes this, not an individual object. Physics deals with collective terms and objects. A collective object is for example the size of a pea or the number of rays. Such collective case never characterizes an individual case, but a certain average over a more or less large number of individual cases. To stay with the example of the size of a pea, we arrange a larger number, say 1000 peas, according to their size and thus find, firstly, the number within certain arbitrary size intervals as ordinates and, secondly, the size of the peas as plots of the abscissa, the distribution curve or distribution function of the collective object. The larger the number is used, the more reliable the average values are found, the more precisely the collective object is defined.

The physical collective objects generally refer to such a large number of individual processes that the approximate definition does not always emerge clearly. This is also the case with the concept of “entropy”, the measure of which is defined as a function of a collective object. For instance, the approximate meaning of the collective object temperature is transferred to the entropy, which is also given an approximate definition that is peculiar to a collective object.

How important the concept of the “collective object” is for the whole of physics is evident from the fact that every physical measurement of any size carried out more than once is a collective object, since every single measurement is subject to an error. The physical measurement of a variable always denotes a certain average value among many individual observations, which is associated with the approximate determination of a physical collective variable.

The fact that entropy is a collective variable is basically the basis of the interest, an argument between Mr Loschmidt and Mr Boltzmann. The former claimed that it was possible to transfer heat from a body with a lower temperature to a body with a higher temperature by means of single or a few gas molecules, the latter proved by calculation that such a transition was not possible with a very large number of, almost infinite, gas molecules. That Loschmidt's idea is based on individual objects, Boltzmann's calculations related to collective objects, apparently went unnoticed by contemporaries of this dispute. The concept of “entropy” is only approximately defined, and that the second law, how broadly its range may be for processes with very large numbers of molecules, is only approximately valid, and only for very large numbers of molecules. For small numbers of molecules the second law is so imprecise that it is to be regarded as practically invalid.

The second law does not have the universal meaning that encompasses all natural processes like the first law, because it only extends to special phenomena of warmth. So it is actually not a main clause, but a subordinate clause. Likewise, a perpetual motion machine of the second type is also to be regarded as producible for a few molecules, likewise still producible for many molecules, and to be regarded as

practically no longer producible for an enormous number of molecules. The impossibility of building a perpetual motion machine of the second kind does not exist in principle, but only relates to the degree of approximation of the technical production. In contrast, the perpetual motion machine of the first kind seems to be fundamentally impossible.

References

Carnap R. Beobachtungssprache und theoretische Sprache // Dialectica, 1958. № 12.

Hempel C. The Theoretician's Dilemma // Minnesota Studies in the Philosophy of Science II. – Minneapolis, 1958.

Hempel C. Aspects of Scientific Explanation. – N.-Y., 1965.

Hempel C. The Meaning of Theoretical Terms – a Critique of the Standard Empiricist Construal // Logic, Methodology, and Philosophy of Science IV. – North Holland, 1973.

Henrich D. Identität: Begriffe, Probleme, Grenzen // Identität. – München, 1996.

Kornwachs K. Strukturen technologischen Wissens: Analytischen Studie zu einer Wissenschaftstheorie der Technik. – Berlin, 2012.

Luhman N. Soziale Systeme: Grundriß einer allgemeinen Theorie. – Frankfurt, 1984.

Mach E. Die Mechanik – historisch-kritisch dargestellt. – Darmstadt, 1963.

Majer U. Sind "physikalische Begriffe" definierbar? // Aspekte der physikalischen Begriffsbildung. – Braunschweig/Wiesbaden, 1979.

Poincare H, Lindemann F.& L. Wissenschaft und Hypothese. – Leipzig, 1914.

Scheibe E. On the Structure of Physical Theories // Acta Phil. Fennica, 1978. V. 30, № 2-4.

Sneed J. The Logical Structure of Mathematical Physics. – Dordrecht, 1971.

Sneed J. Philosophical Problems in the Empirical Science of Science: A Formal Approach // Erkenntnis, 1976. №10.

Sneed J. The Logical Structure of Mathematical Physics. – Dordrecht, 1979.

Sneed J. Structuralism and Scientific Realism // Erkenntnis 1983. №19.

Stachowiak H. Allgemeine Modelltheorie. – Wien/N.-Y., 1973.

Stegmüller W. The Structuralist View of Theories. – Berlin/Heidelberg/N.-Y., 1979.

Stegmüller W. Probleme und Resultate der Wissenschaftstheorie und analytischen Philosophie. Band II: Theorie und Erfahrung. – Berlin/Heidelberg/N.-Y., 1970-1986.

Suppe F. The Structure of Scientific Theories. – Illinois, 1974.